THE DISTRIBUTION OF BENTHOS IN RED ROCK RESERVOIR, IOWA

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by

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INTRODUCTION

The benthos is an association of species populations of plants and animals that live in or on the bottom of a body of water. Ranging from shore to considerable depths and often consisting of a number of different substances, the bottom presents an impressive variety of environmental complexes. Probably no other community within a lake provides greater variety of kinds and numbers of organisms. The composition of benthic communities is controlled by numerous components, some of which appear to operate directly to limit certain species and in other instances suggest interrelationships of several variables. The physiochemical and biological features of water seem to be among the more conspicuous influencing factors (Reid, 1961).

A reservoir varies in a number of physical details from glaciated lakes. Inlets and outlets of glaciated lakes are near the surface, but water can leave a reservoir at any of several depths. A reservoir bottom has a regular slope from head to tail that was established by the river before impoundment. Glaciated lakes normally began as oligotrophic bodies of water resting on clay, sand and gravel. Reservoirs, on the other hand, inundate rich bottom lands and fertile topsoils on river slopes and normally begin their lives with high productivity potential (Neel, 1963).

The mud-water interface of a lake has many characteristics which can limit the kinds and numbers of organisms.

Depth has been shown to play a major role in distribution of benthic organisms (Paloumpis and Starrett, 1960; Teter, 1960; Stahl, 1966; Johnson and Matheson, 1968; Roth, 1968; Craven and Brown, 1969; Heuschele, 1969). Juday (1921) found the numbers of *Corethra punctipennis* (Say) increased progressively with depth in Lake Mendota. Studies on West Lake Okoboji showed that the highest number of tubificid worms was found at the deepest sample sites (Bardach, Morrill and Gambony, 1951).

The benthos studies of Davis and Hughes (1966) and Fillion (1967) indicated that two important factors affecting benthos composition were water fluctuations and retention time. In a study of the Lewis and Clark Reservoir on the Missouri River, low numbers of organisms were attributed to a relatively low retention time of 8 to 10 days (Schmulback and Sandholm, 1962).

Another characteristic which is important to the distribution of the benthic organisms is the amount of organic material found in the bottom mud (Paloumpis and Starrett, 1960; Clampitt, Waffle and Bovbjerg, 1960; Buscemi, 1961; Hiltunen, 1969). Carr and Hiltunen (1965), in a study of the bottom fauna of Western Lake Erie from 1930 to 1961, showed that the increase of Oligochaetes, midges, clams, and snails was related to increased enrichment of the bottom sediment.

Dissolved oxygen has been shown to change the number and kinds of benthic organisms. Buscemi (1961) and Reid (1961) stated that Oligochaetes and Chironomids were found in waters with low dissolved oxygen values.

The bottom vegetation can also play a role in limiting distribution of benthic organisms (Mrachek and Bachmann, 1967). In a study by Kugler and Chen (1968) fish were shown to limit larvae populations living on the muddy bottom of the lake.

Few benthological studies have been done on reservoirs in Iowa and none on Red Rock Reservoir. The reservoir was completed in March, 1969, and reached conservation level in June, 1969. The main purposes of the reservoir are flood control, recreational uses, and low flow augmentation. Since fishing is one of the major recreational uses, the effect which impounding water has on bottom organisms is of importance. Prior to impoundment, there were no preliminary studies of the bottom fauna.

The purpose of this study on Red Rock Reservoir was (a) to determine the kinds and distribution of benthic organisms, and (b) to correlate the physicochemical parameters with composition and distribution of these organisms.

MATERIALS AND METHODS

Red Rock Reservoir, located in central Iowa on the Des Moines River, is approximately 11.3 miles long with a flood control pool of 33.5 miles in length. The conservation pool is 8,950 acres; and the flood control pool is 65,500 acres. Three transects across the reservoir with three sample sites along each were selected for collection of benthic organisms (Figure 1). Transect 1, in the deepest part of the impoundment, was usually 8 to 10 meters at each sample site. Transect 2 included a sampling site within Whitebreast Bay, a site over the old river channel, and a third shallow site. Transect 3 was between two bluffs, Elk and Eagle, with one sampling site over the old river channel, the other in the middle of the transect, and the third located approximately three-fourths along the transect from the south side.

Sampling was done every four weeks from April 24 through November 13, 1970, except for a one week delay when the boat was not available. Samples were taken during the morning between 9:00 A.M. and 1:00 P.M. The boat and motor were made available by Jim Mayhew, Assistant Supervisor, Biology Division, Iowa Conservation Commission.

Bottom samples were taken with the Petersen dredge. This sampling device was selected because of the presence of large pieces of debris found on the bottom sediments. To facilitate the separation of organisms from the sediment, a

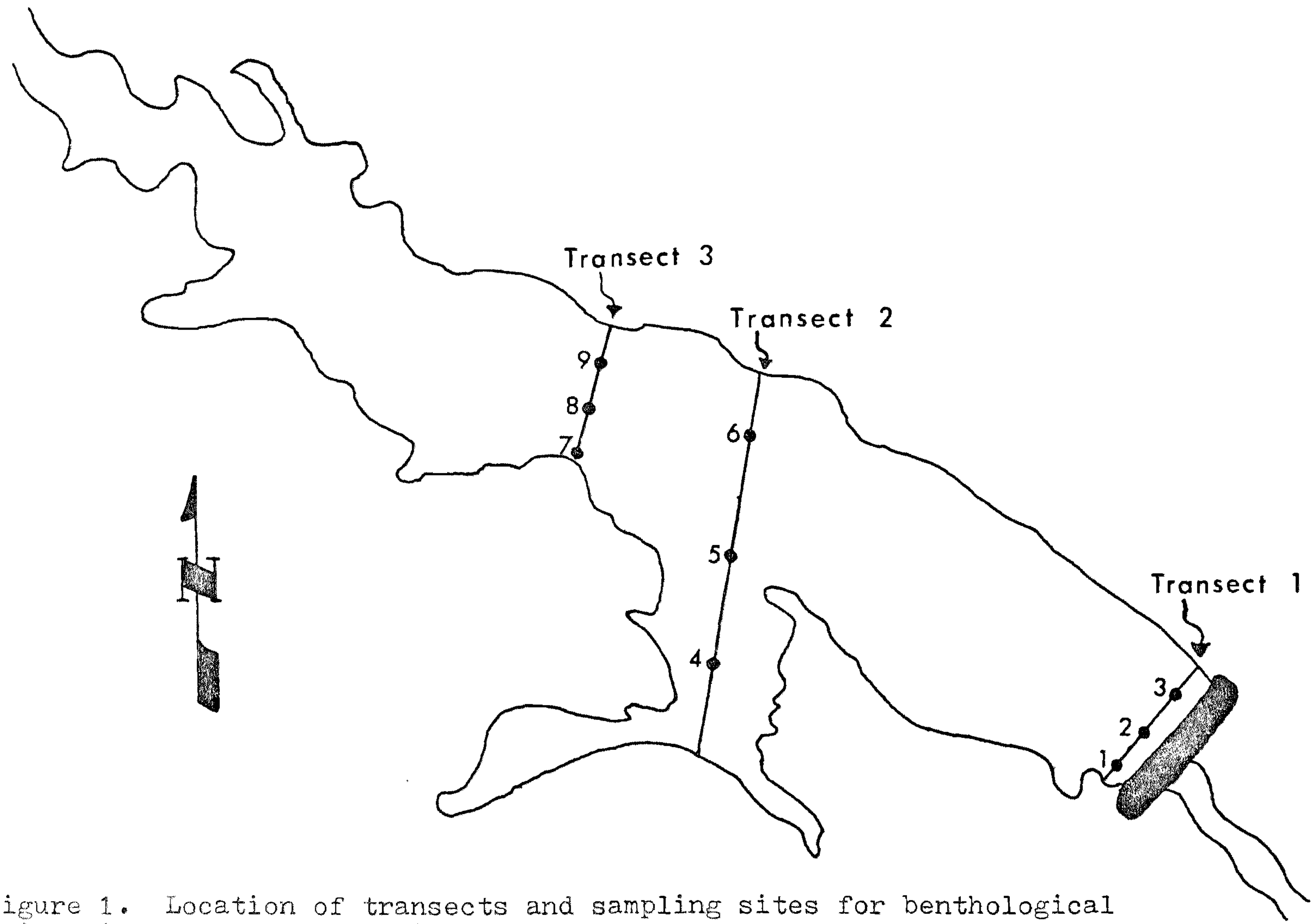

Figure 1. Location of transects and sampling sites for benthological collections in Red Rock Reservoir, Iowa, 1970.

large sieve was constructed from a galvanized bucket with three side-panels cut out and replaced with Tyler No. 40 copper screening.

At each station, two dredge samples were taken and placed into the bucket sieve. A sample of mud from the bucket was placed in a small jar for later analysis of pH and volatile solids. The sieve was placed over the side of the boat and swirled in the water until the smaller particles were removed. The remaining material was placed in a glass jar, preserved with 37 per cent formalin and taken back to the laboratory.

The preserved mud and organism mixture was placed in a U.S. Sieve Series No. 30 mesh and washed under tap water. The organisms were sorted from the debris and stored in 10 per cent formalin. The organisms from both dredge samples were combined at this point. These organisms were, later placed into 70 per cent alcohol, counted, and identified (Johannsen, 1934).

The non-sieved samples were dried and analyzed for pH using a LaMotte-Morgan Soil testing set with bromthymol blue as the indicator. Another portion was dried and weighed on a Mettler balance and ignited in an electric muffle furnace at 600°C. After 15 minutes, the crucible was removed, the contents were mixed thoroughly then replaced in the furnace for an additional 15 minutes (Am. Public Health Assoc., 1965). The ash was weighed, after cooling in a desiccator for 30 minutes, and loss on ignition was reported as per cent volatile solids.

A 1200 ml Kremmerer bottle was used to collect water for chemical analysis. This sample was collected one meter above the mud-water interface. Part of the water was placed in B.O.D. bottles and fixed for dissolved oxygen (Am. Public Health Assoc., 1965). The fixed sample was titrated for dissolved oxygen using the modified Winkler method. The remaining water was placed in glass jars and refrigerated for laboratory analysis of carbon dioxide, total alkalinity, pH, nitrate nitrogen and ortho-phosphate. Carbon dioxide and alkalinity were measured within 72 hours after sampling (Welch, 1948). The pH was determined using the Hach thymol blue tester, Model 17-F. Nitrate nitrogen and ortho-phosphate were measured using the Coleman Junior Spectrophotometer at wavelengths of 520 mu and 670 mu, respectively.

Water depth and temperature were measured with an electrical resistance thermometer which was lowered to the bottom of each station. Daily water levels and inflow and outflow data were obtained from the U.S. Army Corps of Engineers, Knoxville, Iowa.

RESULTS

Physical Conditions

Depths at the stations ranged from $1\frac{1}{2}$ to 10 meters with stations 1, 2, 3, 5, and 7 representing the deep areas of the reservoir. Depth fluctuations occurred from month to month as much as 5 meters at station 1 (Appendix A).

Bottom temperature ranged from 11 to 27°C over the sampling period, with as much as a 3°C difference among the stations during any one sampling time (Appendix A). There was no temperature stratification in the reservoir except for a temporary one at Station 8 in July.

The water level of the reservoir remained relatively constant during this study, around 221 meters above sea level. The discharge rate and retention time varied over the eight month period. The average weekly discharge rate ranged from 11.8 to 497.2 M^3/second. The high discharge rates occurred from April to June with a noticeable decrease in July and August. Retention time ranged from 2.6 to 108.9 days with the low retention times occurring from April to June (Appendix B).

Chemical Conditions

The water pH ranged from 7.5 to 8.5 over the sampling period, with a noticeable decrease in August. The pH remained fairly uniform from station to station each month (Appendix C). Total alkalinity ranged from 55 to 244 mg/l; the highest values occurred in April and gradually decreased to a low in August (Appendix C). Nitrates and ortho-phosphates ranged from 0.0 to 9.8 mg/l and 0.2 to 2.0 mg/l, respectively with the lowest values of nitrates occurring in April and August (Appendix C). Dissolved oxygen ranged from 0.6 to 10.4 mg/l with the lowest values in August; whereas carbon dioxide content ranged from 30 to 183 mg/l with the highest concentration occurring in August (Appendix C). The field methods used for water pH and free CO_2 content gave rather unreliable results.

Mud pH ranged from 6.4 to 7.4 and was relatively uniform throughout the sampling period. The organic mud content, reported as per cent volatile solids, ranged from 0.8 to 11.2 per cent. The per cent volatile solids varied from month to month and from station to station with the lowest values consistently occurring at Station 2 (Appendix A).

Benthos Populations

Three different groups of organisms were identified from Red Rock Reservoir: Chironominae, Oligochaeta, and *Chaoborus punctipennis* (Say). The Chironominae populations, referred to in this paper as *Chironomus*, were small. A total of 27 *Chironomus* was found during the sampling period and these were found only at Stations 3, 4, and 6 (Table 1). The Oligochaeta were more abundant with a total of 81 organisms collected; they were present only at the deeper Stations 2, 3, 5, and 7 (Table 1). *Chaoborus punctipennis* (Say) was the dominant organism with a total 912 collected over the eight month period. They were present at all stations but were more numerous in the deeper areas of the reservoir. Stations 1, 3, 5, and 7 had the highest number of *Chaoborus* with values of 35, 26, 16, and $22/m^2$, respectively. Station

Table 1. Comparative densities (no./M^2) of benthic organisms collected at each station in Red Rock Reservoir, 1970.

Date Taxonomic group	STATIONS 1	2	3	4	5	6	7	8	9
April 24									
Chironomus	0	0	0	10	0	0	0	0	0
Oligochaeta	0	0	0	0	5	0	17	0	0
Chaoborus	32	27	81	0	48	0	43	0	21
Total	32	27	81	10	53	0	60	0	21
May 22									
Chironomus	0	0	5	0	0	0	0	0	0
Oligochaeta	0	5	0	0	0	0	0	0	0
Chaoborus	22	0	5	0	5	5	11	0	0
Total	22	5	10	0	5	5	11	0	0
June 19									
Chironomus	0	0	0	0	0	5	0	0	0
Oligochaeta	0	11	11	0	5	0	0	0	0
Chaoborus	5	0	0	11	0	0	0	11	0
Total	5	11	11	11	5	5	0	11	0
July 17									
Chironomus	0	0	0	0	0	0	0	0	0
Oligochaeta	0	5	0	0	0	0	5	0	0
Chaoborus	48	11	5	0	11	5	59	11	0
Total	48	16	5	0	11	5	64	11	0

Table 1. Continued.

Date Taxonomic group	STATIONS 1	2	3	4	5	6	7	8	9
Aug. 14									
Chironomus	0	0	0	0	0	5	0	0	0
Oligochaeta	0	5	0	0	0	0	0	0	0
Chaoborus	5	0	0	0	0	0	0	5	0
Total	5	5	0	0	0	5	0	5	0
Sept. 18									
Chironomus	0	0	0	0	0	0	0	0	0
Oligochaeta	0	0	0	0	0	0	0	0	0
Chaoborus	5	0	59	0	27	5	11	17	5
Total	5	0	59	0	27	5	11	17	5
Oct. 16									
Chironomus	0	0	0	0	0	0	0	0	0
Oligochaeta	0	0	0	0	0	0	5	0	0
Chaoborus	11	5	21	0	11	0	11	11	11
Total	11	5	21	0	11	0	16	11	11
Nov. 13									
Chironomus	0	0	0	0	0	0	0	0	0
Oligochaeta	0	0	0	0	0	0	5	0	0
Chaoborus	150	0	22	5	17	5	11	0	5
Total	150	0	22	5	17	5	16	0	5

Table 1. Continued.

Date Taxonomic group	STATIONS 1	2	3	4	5	6	7	8	9
Study Total									
Chironomus	0	0	5	11	0	11	0	0	0
Oligochaeta	0	27	11	0	11	0	32	0	0
Chaoborus	278	43	193	16	119	20	146	55	42
Total	278	70	209	27	130	31	178	55	42
Mean Density	35	9	26	3	16	4	22	7	5

2, also a deep water area, only had a density of $9/m^2$. Station 4 had a mean density of $3/m^2$ over the sampling period. Starting in April, the Chaoborus showed a gradual decrease at each station with a low in August and subsequent increase in the following months (Table 1).

DISCUSSION

Prior to impoundment the reservoir area had rich soil which should indicate high productivity. However, in terms of total numbers and mean density of benthic organisms, Red Rock was considerably low compared to similar studies by Schmulbach and Sandholm (1962) and Fillion (1967). In a study by Davis and Hughes (1966) on a new reservoir, Bayou D'Arbonne, they found a similar situation and felt that the low numbers were due to the newness of the reservoir. Davis and Hughes found a decrease of 5 oligoehaeta per square meter after impoundment. The established organisms in the old river channel were spreading out and therefore reducing the density of the organisms. This could explain the reasons for the low numbers and density. Small lateral movement by the organisms from the old river channel could also explain the low numbers. The bottom vegetation was very thick in many parts of the reservoir and this could also explain the low numbers. Mrachek and Bachmann (1967) felt that bottom vegetation played a role in limiting the number of Oligochaeta.

The number of different organisms collected at Red Rock Reservoir were only three, this is low compared to other studies by Davis and Hughes (1966) and Fillion (1967). In terms of the physicochemical properties studied there is no obvious reason for this low number of different organisms. However, there is a population of carp and buffalo fish in the reservoir which feed primarily off larvae. They could limit the numbers and kinds of benthic organisms in the reservoir. In the study by Kugler and Chen (1968) they found that during all months of the year, carp fed to a great extent on larvae living on the sandy and muddy bottom.

The water level of the reservoir was kept almost constant over the study period (Appendix B). There was great fluctuations in retention time, and according to Schmulbach and Sandholm (1962) low retention time could be responsible for reduction in numbers of organisms. The low retention at the reservoir could be another factor in explaining the low number of benthic organisms collected. A high number of benthic organisms could be flowing out the impoundment before they are able to become established in their mud environment.

As stated earlier the deepest stations were numbers 1, 2, 3, 5, and 7 (Appendix A). There seemed to be a definite relationship between depth and distribution of organisms (Figure 2). The highest number of Chaoborus occurred at the deep Stations 1, 3, 5, and 7. This relationship between depth and distribution was also reported by Juday (1921),

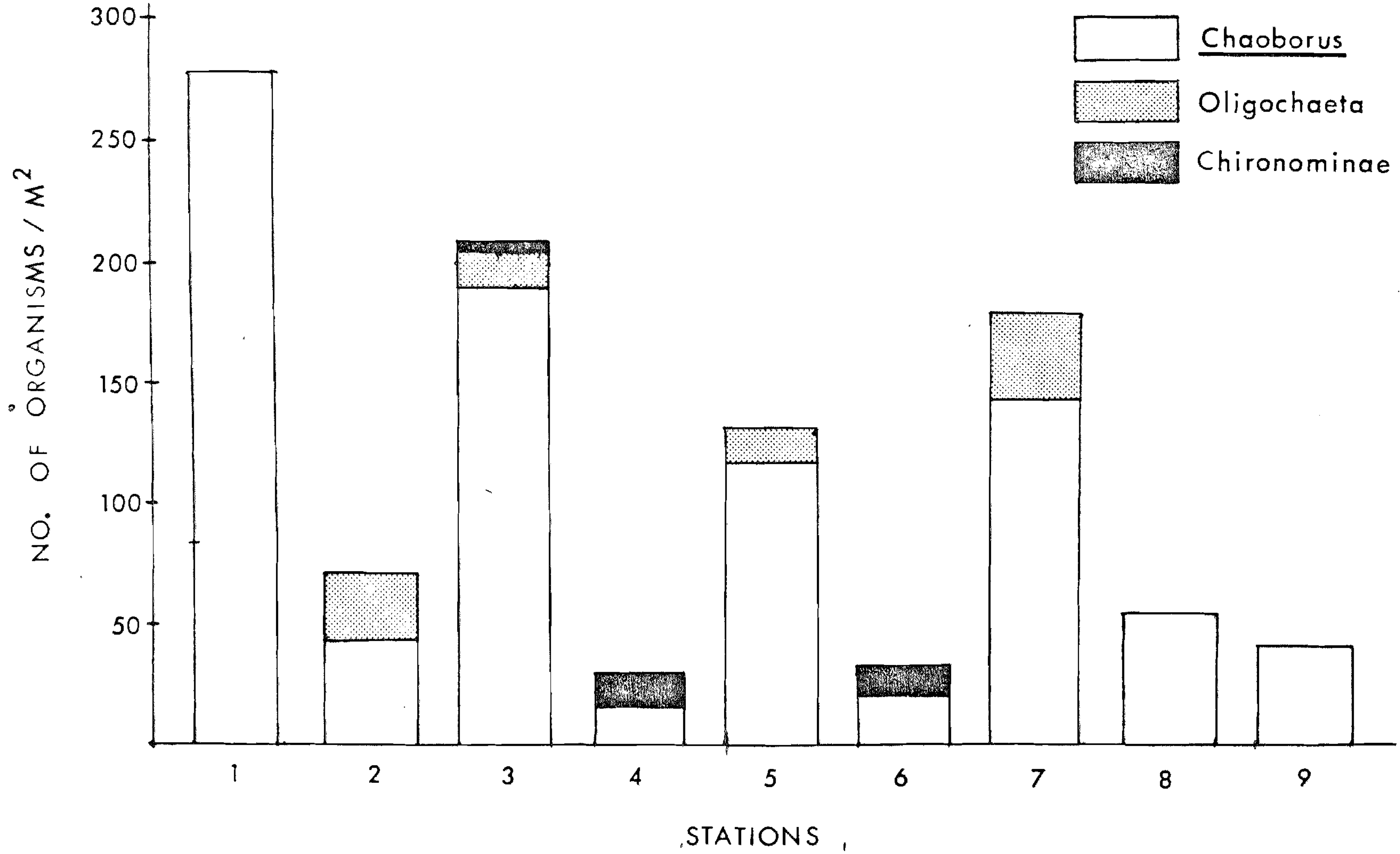

Figure 2. Total number of benthic organisms collected per square meter at each sample site from April through November, 1970, in Red Rock Reservoir.

Paloumpis and Starrett (1960), and Johnson and Matheson (1968). Figure 2 also shows that high numbers of Chaoborus were not found at Station 2 even though it is a deep station. This could be explained by the fact that Station 2 is found close to the outlet of the reservoir. Station 2 has a very sandy bottom with low organic content which could also explain the low numbers of Chaoborus. The aspect of organic content will be discussed in more detail later in the paper.

The Oligochaeta were also found at only the deeper stations (Figure 2). In the study by Bardach, Morrill, and Gambony (1951) they found that the Oligochaeta became more numerous beyond a depth of 25 meters and in the deepest part of the lake, around 39 meters, they were the only macroscopic animals found. However, in Red Rock Reservoir the Oligochaeta were not present at Station 1. No explanation can be offered for this since Stations 1 and 3 were almost identical in their bottom type and physicochemical make-up.

The organic content of the mud seemed to play a role in the number of organisms present in the reservoir. Station 2, in almost every case, had the lowest percentage of organic material (Appendix A). It was the only station which had a reduced number of Chaoborus. In the study by Carr and Hiltunen (1965) they found that the increase in the number of organisms in Western Lake Erie was related to increased enrichment of the bottom sediment. In view of this relationship between depth and organic content at Red Rock it seems that the number and distribution of the Chaoborus are affected by both.

In August there was an unusual decrease in numbers of Chaoborus larvae, which has been previously described by Juday (1921) and Heuschele (1969) in their studies. They found that as the temperature of the water increased, the rate of pupation increased and the number of Chaoborus larvae decreased and this decline in numbers of larvae continued over the summer until a minimum was reached in August. This same phenomenon was recorded in Red Rock. Table 1 shows that in September and the following months there was an appreciable increase in the number of Chaoborus larvae, which Juday also reported. Stahl (1966) indicated that young Chaoborus larvae tended to be benthic during the daytime but migrated vertically at night. In Myers Lake, Indiana, planktonic larvae were found about two meters above the substrate (Stahl, 1966). This may account for the reduced numbers captured in Red Rock Reservoir during the summer months. Since larvae that hatched in May probably would be planktonic during the summer, or located just above the bottom, they would have escaped the dredge.

The gradual decrease in dissolved oxygen in the bottom from April through August corresponded with the gradual decrease in Chaoborus larvae. Since there was no prolonged stratification in the reservoir over the sampling period, the decrease in oxygen could have been due to decreased solubility with increased temperature. Heuschele (1969) reported a similar decrease in oxygen with a corresponding decrease in larvae.

Nitrate-nitrogen and ortho-phosphate values did not seem to play any important role in controlling distribution of the benthic organisms. The water and mud pH also did not seem to affect the distribution of the organisms. These chemical factors would have an indirect relationship on the benthic numbers through the food chain.

For further investigations in the study of benthos, it is recommended that sampling should be on a weekly basis for a more reliable look at changes in the distribution and numbers of organisms. The detection of minor nutrients might also be helpful in receiving a clearer picture of the benthos. Looking at the benthic predators and flow patterns of the reservoir would also help in determination of the distribution. With this information a more realistic estimate of the factors which control distribution and abundance of benthic organisms in a reservoir could be made.

SUMMARY

1. Benthos populations in Red Rock Reservoir were sampled at four week intervals from April through November, using the Petersen dredge. Chemical and physical conditions were determined to correlate with benthos distribution.

2. Three different organisms were collected from the reservoir: Chironominae, Oligochaeta, and *Chaoborus punctipennis* (Say). *Chaoborus* was the dominant species.
3. Station 1 had the highest mean density with 35 organisms per square meter. The total number of organisms collected was low; it is supposed that this is due to the newness of the reservoir.
4. Water retention seemed to play a role in controlling the number of benthic organisms.
5. The main influencing factors in benthic distribution seemed to be water depth and bottom organic content.
6. It is suggested that more samples be taken at each sample site and sampling be repeated at weekly intervals for a more reliable study. Benthic predators should also be studied to see if they are affecting benthic numbers and distribution.

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APPENDIX

Appendix A. Depth, bottom water temperature, mud pH, and organic mud content at each sample site in Red Rock Reservoir, 1970.

Date station	depth (M)	temp. (°C)	mud pH	ORGANIC MUD CONTENT wt. before ignition(gm)	Wt. loss on ignition(gm)	volatile solids(%)
April 24						
1	4.0	11.0	7.2	5.35	0.48	9.0
2	6.0	11.0	7.1	6.42	0.28	4.4
3	5.0	11.5	7.2	3.08	0.25	8.1
4	3.0	11.0	7.2	4.32	0.29	6.8
5	7.0	13.0	7.3	5.29	0.30	5.6
6	1.5	13.0	7.2	6.60	0.29	4.5
7	8.0	13.0	7.0	6.45	0.22	3.5
8	2.0	14.0	7.4	5.50	0.37	6.8
9	2.0	14.0	7.4	5.35	0.35	6.6
May 22						
1	9.0	18.0	---	----	----	---
2	8.0	20.0	7.0	8.45	0.07	0.8
3	7.0	18.0	6.8	4.16	0.20	4.7
4	5.0	20.0	6.4	4.30	0.35	8.1
5	9.0	20.0	7.2	4.87	0.36	7.3
6	4.0	19.0	7.2	5.61	0.44	7.9
7	9.0	20.0	7.4	3.92	0.34	8.6
8	5.0	21.0	7.4	5.07	0.43	8.5
9	4.0	21.0	7.4	6.37	0.39	6.1

Appendix A. Continued.

Date station	depth (M)	temp. (°C)	mud pH	ORGANIC MUD CONTENT wt. before ignition(gm)	wt. loss on ignition(gm)	volatile solids(%)
June 19						
1	7.0	22.0	7.4	7.04	0.42	5.9
2	6.0	24.0	7.0	5.60	0.25	4.5
3	5.0	24.0	7.2	5.34	0.29	5.4
4	2.0	26.0	7.3	4.60	0.43	9.3
5	7.0	24.0	7.3	4.05	0.21	5.1
6	2.0	25.0	7.2	4.13	0.37	8.2
7	6.0	25.0	7.4	2.33	0.23	9.7
8	2.0	25.0	7.4	4.62	0.33	7.2
9	2.0	26.0	7.3	5.59	0.28	5.0
July 17						
1	6.0	25.5	7.2	3.45	0.30	8.9
2	6.0	25.0	7.3	7.35	0.18	2.5
3	5.0	25.0	7.1	3.01	0.23	7.7
4	3.0	26.0	6.4	4.42	0.45	10.1
5	7.0	25.0	7.3	4.14	0.40	9.6
6	2.0	25.5	7.3	2.99	0.19	6.4
7	6.0	25.0	7.2	3.19	0.31	9.8
8	2.0	25.0	7.3	3.28	0.27	8.1
9	2.0	26.0	7.3	4.60	0.41	9.0

Appendix A. Continued.

Date station	depth (M)	temp. (°C)	mud pH	ORGANIC MUD CONTENT wt. before ignition(gm)	wt. loss on ignition(gm)	volatile solids(%)
Aug. 14						
1	6.0	23.0	7.0	4.86	0.43	8.8
2	9.0	23.0	7.0	6.98	0.31	4.4
3	5.0	24.0	7.4	6.20	0.28	4.5
4	2.0	25.0	7.4	5.30	0.52	9.9
5	8.0	24.0	7.4	5.41	0.61	11.2
6	2.0	27.0	7.2	5.86	0.50	8.4
7	8.0	24.0	7.2	6.81	0.67	9.8
8	2.0	26.0	7.2	5.05	0.46	9.1
9	2.0	26.0	7.2	5.97	0.46	7.7
Sept. 18						
1	8.0	17.5	7.1	3.91	0.41	10.4
2	9.0	17.5	7.2	4.95	0.29	5.9
3	6.0	18.0	7.2	5.32	0.49	9.8
4	2.0	16.5	7.3	5.13	0.51	9.9
5	7.0	17.0	7.2	5.71	0.49	8.6
6	2.0	17.0	7.2	6.12	0.58	9.5
7	7.0	17.0	7.3	5.86	0.48	8.3
8	2.0	17.5	---	----	----	---
9	2.0	17.5	7.4	6.45	0.45	7.0

Appendix A. Continued.

Date station	depth (M)	temp. (°C)	mud pH	ORGANIC MUD CONTENT wt. before ignition(gm)	wt. loss on ignition(gm)	volatile solids(%)
Oct. 16						
1	7.0	15.0	7.2	4.52	0.44	9.8
2	10.0	15.5	7.3	5.37	0.33	6.2
3	9.0	15.0	7.3	5.00	0.48	9.6
4	2.0	14.0	7.1	6.09	0.42	9.6
5	7.0	14.5	7.3	5.52	0.40	7.2
6	1.0	14.0	7.4	4.59	0.29	6.3
7	7.0	14.5	7.4	6.69	0.58	8.7
8	1.0	14.0	7.3	8.88	0.25	2.9
9	1.5	14.0	7.4	5.26	0.34	6.5
Nov. 13						
1	6.0	11.0	7.2	5.67	0.58	10.1
2	5.0	11.0	7.3	10.76	0.11	1.0
3	5.0	11.0	7.4	6.47	0.56	8.6
4	2.0	11.0	7.2	4.85	0.38	7.8
5	7.0	11.5	---	----	----	---
6	1.5	11.5	7.1	6.88	0.56	8.1
7	6.0	11.5	---	----	----	---
8	1.0	12.0	7.3	7.99	0.46	5.7
9	1.0	12.0	7.3	4.82	0.46	9.6

Appendix B. Water level(M. above sea level), average discharge(M^3/sec.), retention time(day) in Red Rock Reservoir, 1970. (U.S. Army Corps of Engineers, Knoxville, Iowa)

week ending	water level	average discharge	retention time
4/17	221.6	213.6	6.0
4/24	221.3	227.3	5.6
5/1	221.1	211.2	6.1
5/8	221.1	128.9	10.0
5/15	221.3	161.6	8.0
5/22	223.6	497.2	2.6
5/28	222.6	491.8	2.6
6/5	221.2	175.0	7.3
6/12	221.1	117.2	11.0
6/19	221.3	121.2	10.6
6/26	221.2	116.0	11.1
7/2	221.2	71.0	18.1
7/10	221.2	48.8	26.3
7/17	221.2	37.4	34.4
7/24	221.2	28.5	45.1
7/31	221.2	28.6	44.9
8/7	221.2	36.0	35.7
8/14	221.4	179.7	7.2
8/21	221.2	37.9	37.9
8/28	221.2	25.3	25.3
9/4	221.2	12.7	101.5

Appendix B. Continued.

week ending	water level	average discharge	retention time
9/11	221.2	11.8	108.9
9/18	221.4	43.0	29.9
9/25	221.4	74.2	17.3
10/2	221.3	62.9	20.4
10/9	221.2	17.7	72.6
10/16	221.6	159.2	8.1
10/23	221.1	78.2	16.4
10/30	221.0	112.0	11.5
11/6	221.1	64.4	20.0
11/13	221.2	88.7	14.4

Appendix C. Chemical analysis one meter off the bottom at each sample station in Red Rock Reservoir, 1970. Except for pH all units are in mg/l. D.O. = dissolved oxygen, NO_3-N = Nitrate nitrogen, alkal. = total alkalinity, pH = water pH, O-PO_4 = ortho-phosphate, CO_2 = free carbon dioxide.

Date station	D.O.	NO_3-N	alkal.	pH	O-PO_4	CO_2
April 24						
1	8.2	2.2	198	8.1	0.7	30
2	8.6	2.2	178	8.3	0.3	50
3	8.6	1.8	196	8.1	0.4	54
4	4.4	2.2	221	8.3	0.2	78
5	9.2	1.4	235	8.3	0.4	81
6	9.2	3.0	237	8.3	0.4	61
7	10.0	2.2	241	8.3	0.5	49
8	9.8	2.1	244	8.4	0.4	58
9	9.2	2.2	240	8.3	0.7	84
May 22						
1	---	4.4	155	8.0	0.3	30
2	---	4.4	162	8.3	0.3	45
3	---	6.0	159	8.1	0.3	62
4	---	5.2	141	8.4	0.2	72
5	---	5.2	185	8.3	0.4	85
6	---	5.2	197	8.4	0.3	59
7	---	6.8	198	8.3	0.3	60
8	---	6.8	218	8.4	0.3	63
9	---	6.0	218	8.5	0.3	75

Appendix C. Continued.

Date station	D.O.	NO_3-N	alkal.	pH	O-PO_4	CO_2
June 19						
1	2.8	5.6	238	7.9	0.4	59
2	5.6	5.2	230	8.0	0.5	65
3	5.6	5.2	236	8.1	0.5	73
4	6.4	9.8	232	8.2	0.2	84
5	4.8	5.2	237	8.0	0.6	88
6	5.2	4.4	229	8.3	0.4	92
7	4.0	5.2	209	8.3	0.3	83
8	4.8	5.2	214	8.2	0.3	75
9	4.0	5.2	219	8.4	0.5	69
July 17						
1	2.0	7.2	184	8.1	0.5	60
2	4.0	7.2	203	8.2	0.6	71
3	6.0	5.2	199	8.3	0.8	64
4	7.6	2.0	177	8.0	0.7	81
5	4.4	3.6	168	8.1	0.5	80
6	6.8	2.8	172	8.2	0.8	88
7	3.0	2.0	181	8.3	1.1	81
8	8.2	0.0	182	8.4	0.5	79
9	3.2	2.8	181	8.4	1.6	76

Appendix C. Continued.

Date station	D.O.	NO_3-N	alkal.	pH	O-PO_4	CO_2
Aug. 14						
1	0.6	2.8	85	7.8	0.4	160
2	0.6	3.6	93	7.7	0.2	173
3	1.4	2.8	95	7.7	0.3	157
4	4.0	3.6	80	7.5	0.6	168
5	2.6	2.8	95	7.6	1.0	183
6	5.2	3.6	95	7.7	0.4	161
7	1.4	2.0	123	7.7	1.1	150
8	2.0	5.2	137	7.6	0.4	167
9	5.0	4.4	122	7.5	2.0	169
Sept. 18						
1	5.6	4.4	81	7.7	0.4	80
2	6.2	4.4	140	7.7	0.5	78
3	6.2	3.6	142	7.6	0.4	80
4	6.2	2.8	121	7.5	0.2	90
5	6.2	7.2	170	7.7	0.7	88
6	7.0	3.6	170	7.5	0.6	83
7	5.8	2.8	165	7.5	1.0	90
8	5.0	4.4	106	7.8	0.8	84
9	5.8	3.6	104	7.8	0.8	85

Appendix C. Continued.

Date station	D.O.	NO_3-N	alkal.	pH	O-PO_4	CO_2
Oct. 16						
1	8.2	6.0	55	7.9	0.5	52
2	8.4	3.6	125	7.8	0.5	48
3	7.6	2.8	118	7.8	1.0	39
4	9.0	2.8	107	7.9	0.7	35
5	9.0	4.4	162	7.7	0.6	47
6	9.6	4.4	177	7.9	0.7	42
7	9.0	2.8	198	8.0	0.7	48
8	9.8	4.4	207	8.0	0.7	41
9	9.8	4.4	205	7.9	0.7	45
Nov. 13						
1	10.4	5.2	128	7.9	1.8	56
2	9.0	4.4	136	7.9	1.8	51
3	10.2	3.6	125	8.0	1.0	47
4	9.4	3.6	129	7.7	1.6	41
5	8.0	4.4	158	7.9	0.6	49
6	9.0	3.6	179	7.9	1.0	55
7	9.2	3.6	201	8.0	0.6	46
8	8.0	2.8	202	7.9	1.1	42
9	9.0	4.4	196	7.9	0.6	44